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A DESCRIPTIVE SURVEY OF THE HEAD OF CARMEL SUBMARINE CANYON

by

Carl Arthur Moritz

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A DESCRIPTIVE SURVEY OF THE HEAD OF

CARMEL SUBMARINE CANYON

by

Carl Arthur Moritz, Jr.

December 1968

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A DESCRIPTIVE SURVEY OF THE HEAD OF CARMEL SUBMARINE CANYON

by

Carl Arthur Moritz, Jr.
Lieutenant, United States Navy
B.S., Naval Academy, 1962

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN OCEANOGRAPHY

from the

NAVAL POSTGRADUATE SCHOOL
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ABSTRACT

Scuba dive observations made in Carmel Submarine Canyon revealed the existence of rock outcrops of granodiorite on both sides of the canyon head. Five distinct bottom types were found: (1) rock outcrops and boulders, (2) coarse sand, (3) fine sand containing benthic organisms, (4) a silty clay layer underlying coarse sand, and (5) an organic sediment mat. Rocky bottomed terraces on both sides of the canyon head are at the same level and appear to have been eroded at a previous lowered sea level. The coarse sand areas, characterized by steep slopes, are considered to be areas of active sand movement. The fine sand bottoms were found to be relatively stationary although dead kelp material moves over its surface. Thin silty clay deposits considered to be of lagoonal or estuarine origin are found underlying sand at the north side of the canyon head. An organic sediment mat of undetermined thickness was found in a swale which appeared to be a slump scar. Mechanical erosion of the rock from both sand movement and the action of encrusting organisms is evident.

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ACKNOWLEDGMENTS

The author wishes to express appreciation for the advice and encouragement of Professor Warren C. Thompson under whose direction this study was carried out, and for photographic and other materials provided by an Office of Naval Research Foundation Grant to Professor Thompson.

In addition, the author is indebted to Lieutenant S. R. Wallin, USN, who, while working on a related study, was a most able and enjoyable diving partner. Also especially helpful was Commander D. R. Ferrin, USN (Ret), whose diving assistance and knowledge of the Carmel Canyon area was most valuable. Other diving partners included Lieutenants B. R. Googins and R. J. Lennox, USN, Major W. H. Bond, USMC, and T. E. Maudlin.

Appreciation is also expressed to Mr. Charles Mehlert and Mr. Donald Rich of the Monterey Office of the California Department of Natural Resources, Division of Beaches and Parks, for their whole-hearted cooperation in this study.

INTRODUCTION

A. OBJECTIVE

During the spring and summer of 1967, the author made several recreational dives in and around the head of Carmel Submarine Canyon and became fascinated by the great variety of geological and biological features available in this small underwater area. A literature survey revealed that relatively little has been done by way of direct observation of Carmel Submarine Canyon. To date the only extensive detailed underwater observation of Carmel Canyon was a biological exploration by McLean (1968). It was the author's purpose to conduct a comprehensive underwater examination of the canyon head. The picture derived of the underwater canyon that is presented herein incorporates observations and results from previous studies.

B. PAST STUDIES

Shepard and Emery (1941) made a detailed bathymetric survey of the Carmel Canyon head and concluded that from 1934 to 1939 a net fill amounting to 18 feet had taken place along the floor of the canyon in the inner section close to the beach. They felt that deposition was so rapid that the head would be largely filled within a few years unless a slide occurred.

Martin (1964), in a structural study of the Monterey Canyon system, pointed out that Carmel Canyon trends due west in a straight line for 3 miles and then abruptly turns

northwest for 12 miles before intersecting Monterey Canyon (Figure 1). The nearshore reaches of Carmel Canyon are reported as containing igneous rocks of granodioritic composition. Because of the proximity to the Santa Lucia granodiorite exposed in the area, the igneous rocks collected from the seafloor are considered part of the same pluton. These rocks are dated as late Cretaceous or about 81.6 million years. Martin reported that Monastery Beach at the head of Carmel Canyon (Figure 2) was composed of sands which are apparently weathered from the granodiorites along the immediate coast. Sediments from the canyon axis were also found to consist principally of material derived from a granodiorite source. Martin goes on to propose the genesis of Carmel Canyon in post-Late Cretaceous time and discusses its relationship to Monterey Submarine Canyon.

Dill has made several dives into the head of Carmel Canyon and reported precipitous granite walls with several tributaries entering as hanging valleys (Shepard and Dill, 1966).

McLean (1968), beginning in the fall of 1960, made some 50 to 60 biological collecting dives on the rock outcrop located on the northern side of the canyon head. About one acre of area was covered at depths ranging from 60 to 200 feet. He was able to identify approximately 500 species of invertebrates and algae, including 122 species of mollusks.

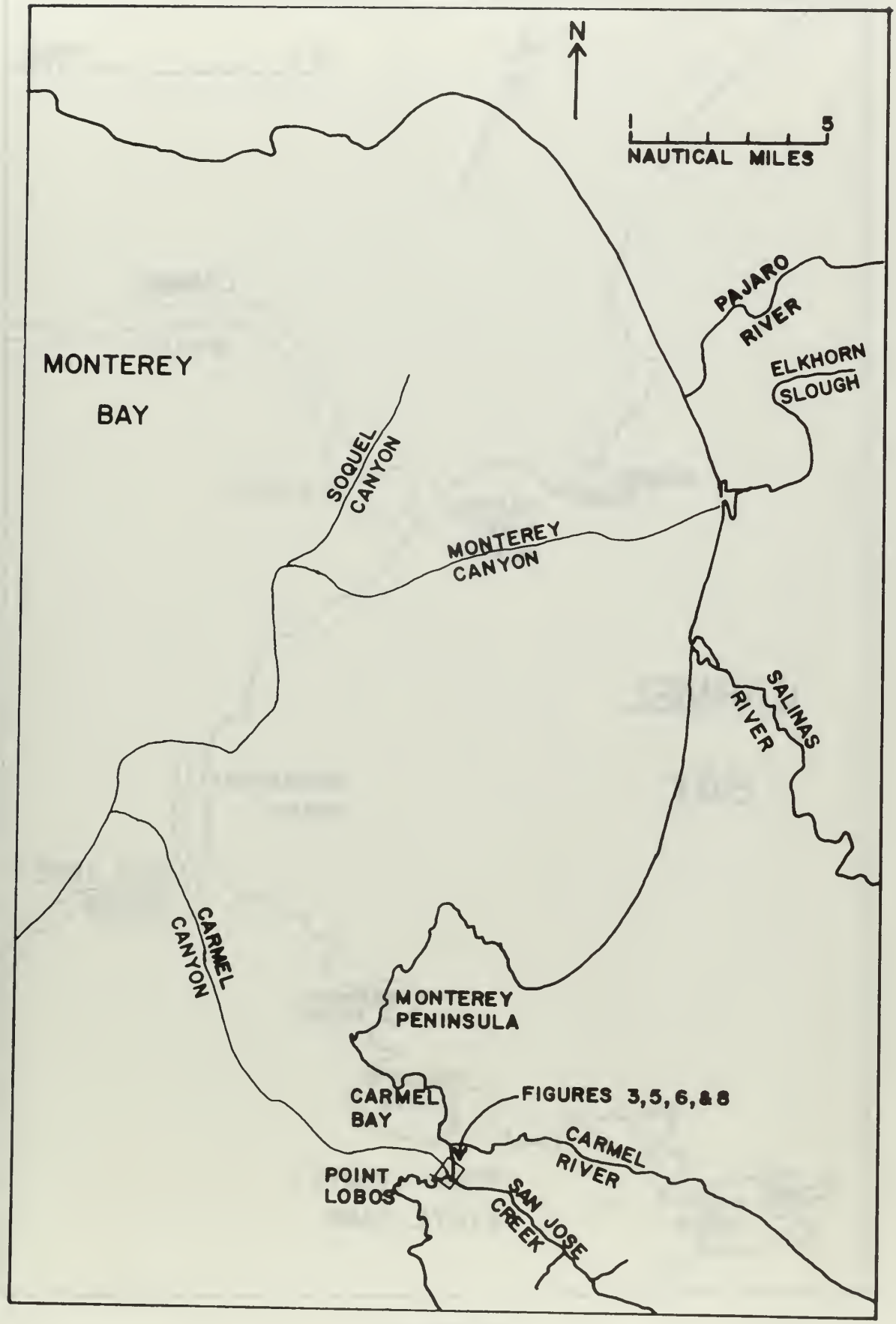

FIGURE 1

Map of Monterey Bay Region

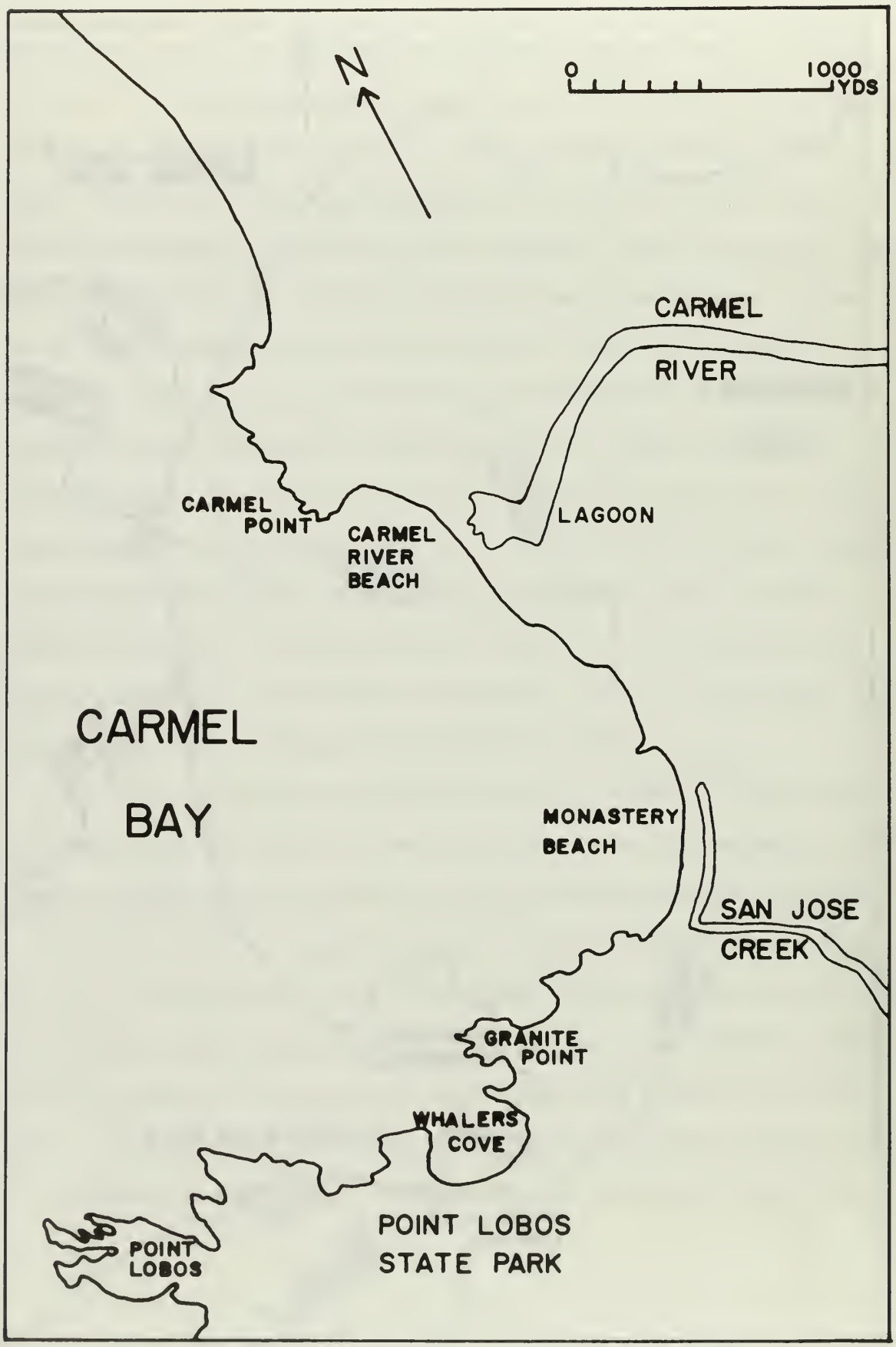

FIGURE 2

Map of Carmel Bay

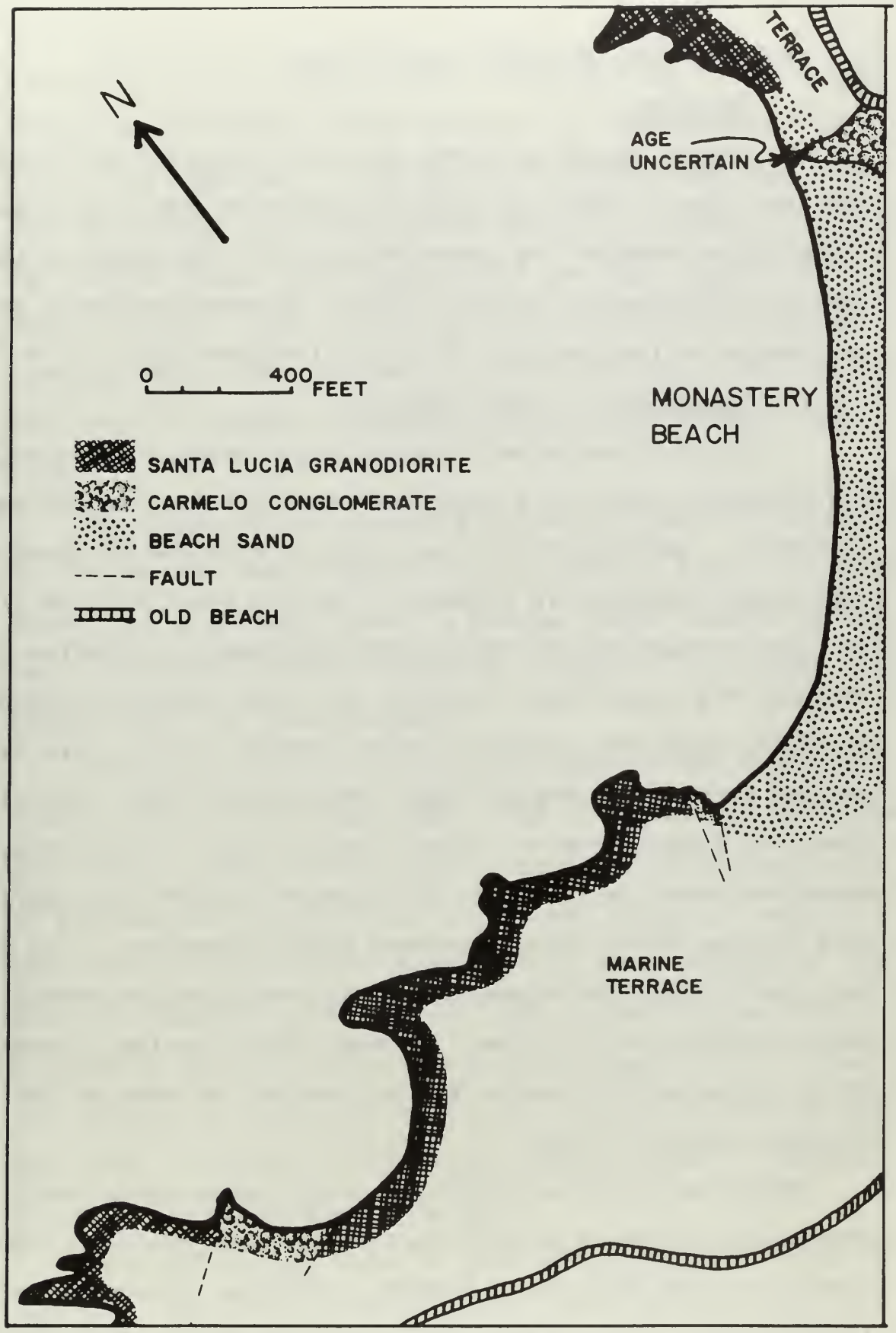

FIGURE 3

Physiographical and Geological Features Near Carmel Canyon Head Area (Map)

C. GEOMORPHOLOGY OF CARMEL CANYON AREA

1. Location

Carmel Canyon in Carmel Bay is located at the mouth of San Jose Creek, about one-half mile south of the point where Carmel River reaches the ocean (Figure 2). The beach at the head of the submarine canyon is known as Monastery Beach and is located at latitude 36° 32' N and longitude 121° 56' W.

2. Topography and Rock Outcrops

The southern edge of Carmel Bay between Granite Point and Monastery Beach is a rocky sea cliff about 20 and 45 feet in height. Landward of the sea cliff at a height of about 65 feet above sea level is evidence of an old beach (Figure 3). The area between the cliffs and the old beach is a marine terrace, the upper layer of which is a thin stratum of unconsolidated sands and gravels. These terrace gravels were deposited probably during the last interglacial epoch when sea level was higher than at present (Bowen, 1965). Shell fragments are found in places on the terrace deposits and represent kitchen debris from abandoned Indian campsites. One of the granodiorite exposures on this terrace contains several Indian grain-grinding holes. Another higher marine terrace at an approximate elevation of 300 feet may be seen on the hillside behind the bay.

Beginning at Granite Point in Point Lobos State Park, the cliffs are about 30 feet high and are composed of granodiorite of the Santa Lucia Formation of late Cretaceous age (Bowen, 1965). To the east, near the boundary of Point Lobos

State Park, is an outcrop about 100 yards wide of the Carmelo Formation (Paleocene) which consists of conglomerate, sandstone, and mudstone in a steep fault contact with the granodiorite (Figure 3). Some graded bedding is evident in places. The cobbles within the conglomerate are well rounded and of various sizes. They are mostly of volcanic origin and are composed mainly of rhyolite and dacite porphyry. The Carmelo Formation is exposed in several parts of Point Lobos State Park.

The granodiorite continues eastward around the shoreline of the bay and ends abruptly at the southern edge of Monastery Beach. At this point there is another small outcrop of Carmelo conglomerates and sandstones (Figure 3) in a steep fault contact with the granodiorite.

Monastery Beach lies along the front of the alluviated lower course of San Jose Creek. The beach is about 700 yards long and is composed of coarse-grained quartz-feldspar sand of principally granodioritic origin and secondary amounts of metamorphic constituents, mainly quartzite. Pebbles of dacite and rhyolite prophyry are found in small amounts and presumably come from the Carmelo conglomerate in the area. A few pebbles of siliceous shale were also found and presumably are from the Monterey Formation (middle Miocene) that outcrops in the hills behind the bay.

The entire beach face is very steep varying between 10° and 35°. The crest of the beach is about 15 feet above the MLLW tide level and acts as a barrier which normally prevents

San Jose Creek from emptying into the ocean. The beach face is crescent shaped and is usually marked over its entire length by pronounced cusps.

San Jose Creek enters the backshore area near the center of the beach (Figure 2). The creek bed turns north and runs parallel to the beach crest to the north end of the beach where it is blocked most of the time by the beach crest. San Jose Creek breaks through the bar on rare occasions when the runoff is sufficient (Figure 4). The entire creek bed behind the beach crest is normally dry except after heavy rains or during periods of heavy surf causing overwash into the backshore area.

At the northern end of the beach is a small outcrop of sandstone and conglomerate, which may be a part of the Chamisal Formation (middle Miocene) which is found on a ridge behind the Carmelite Monastery. The pebbles and boulders within the conglomerate are very angular indicating local origin, and display graded bedding. They are composed of granodiorite and shale. Lying directly on this formation is a thin layer of clayey black humus covered by rounded pebbles and boulders within a matrix of sandy soil. The pebbles and boulders are probably the remains of an old beach terrace (W. C. Thompson, personal communication).

Extending upcoast from the north end of Monastery Beach is a low seacliff composed of granodiorite. It extends several hundred yards to Carmel River Beach and is interrupted in several places by small pocket beaches.

FIGURE 4
Photograph of San Jose Creek Breakthrough

3. Relation to Faults

Martin (1964) reported that the head of Carmel Submarine Canyon is fault controlled and quotes Bowen as stating that a fault exists which runs east-west along the San Jose Creek Canyon. Bowen calls this the Carmel Valley Fault and reports a difference in Miocene foraminiferal fauna existing in strata on opposing sides of the valley.

Martin suggests that erosion of Carmel Submarine Canyon may have been facilitated by a zone of weakness along this fault. He further suggests that the northern side of the canyon may be the scarp of an up-thrown block. As evidence indicating this, he cites scuba dives into the head which show a steep north wall composed of granodiorite and a south wall covered by sloping sand deposits.

4. Type of Canyon

Shepard and Dill (1966) describe Carmel Submarine Canyon as a drowned river valley with a dendritic tributary system of several arms extending into bays along the shore. They further state that the canyon appears to be a seaward extension of San Jose Creek Canyon, the mouth of which has been filled with alluvium by San Jose Creek. Both the land canyon and submarine canyon are cut in granodiorite at their juncture at the coast, and both are steep walled. Measurements by Shepard and Dill show that the average gradient of the land canyon to the coast is one-fifth that of the submarine canyon.

FIELD WORK

A. DIVING SCHEDULE

The observations reported in this thesis are largely visual and a result of numerous scuba dives into and around the head of Carmel Canyon. General exploratory dives began in January 1968. These dives were made with the objective of exploring as much area as possible and to become familiar with its underwater topography. These dives were mostly made on weekends and were unrecorded for the purposes of this thesis. The total area covered by these initial dives and the subsequent recorded dives was about 20 acres (Figure 5). A series of 16 diving surveys were later made from July through November 1968. The logs of these dives are presented in Appendix I.

All dives were conducted as a joint operation with Lieutenant S. R. Wallin, USN, who was conducting a study of the sediments in and around the head of Carmel Submarine Canyon.

B. REFERENCE STAKES

The first task undertaken underwater was to plant reference stakes along the 100-foot contour and to measure the sand level and slope angle at the stakes. The 100-foot level was chosen in order to minimize the effect of sand movement by surface swell and yet be shallow enough to allow sufficient bottom time for diving. It was hoped that areas of sediment transport into the canyon could be determined from changes in

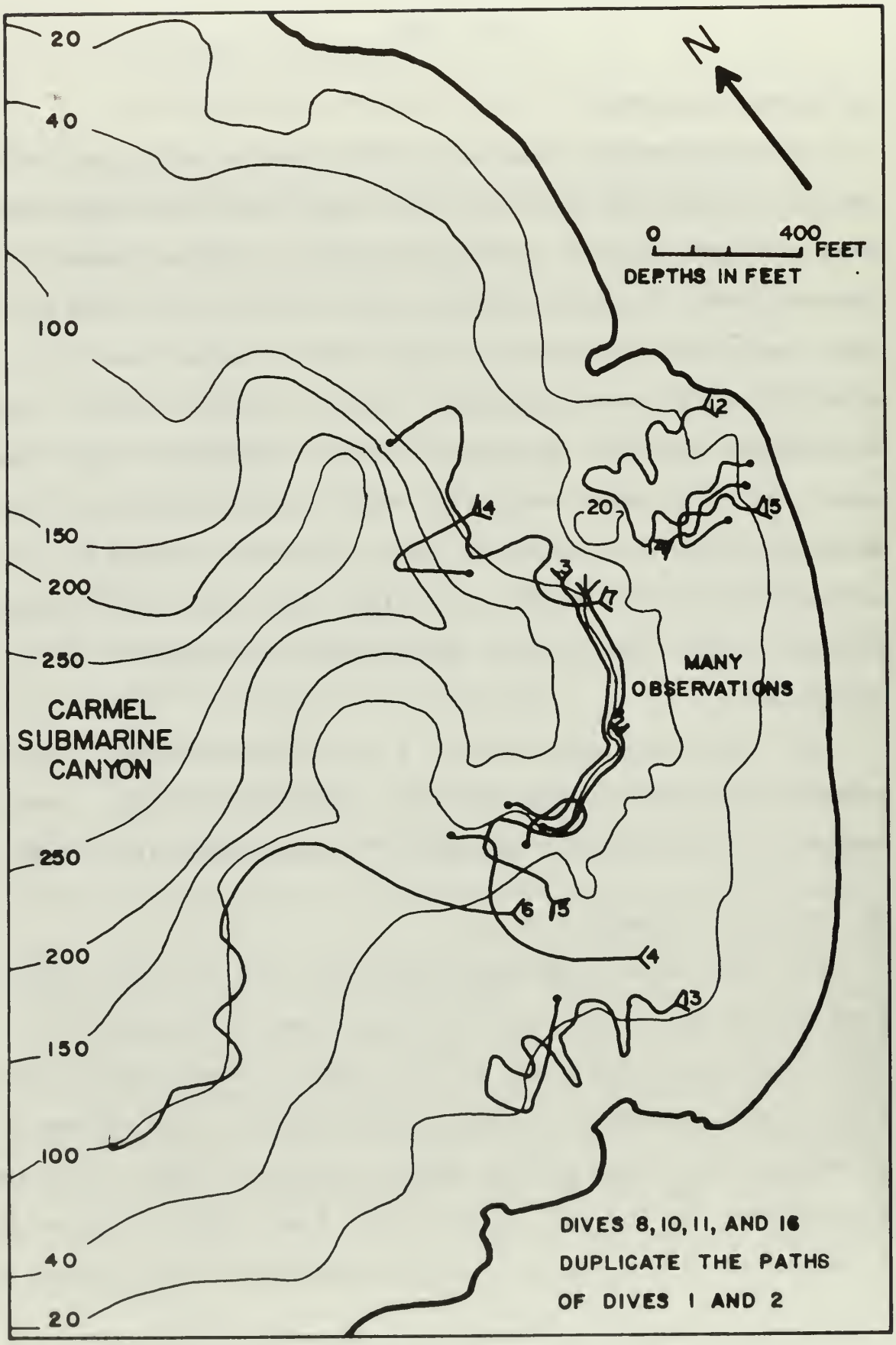

FIGURE 5

Chart Showing Path of Dives

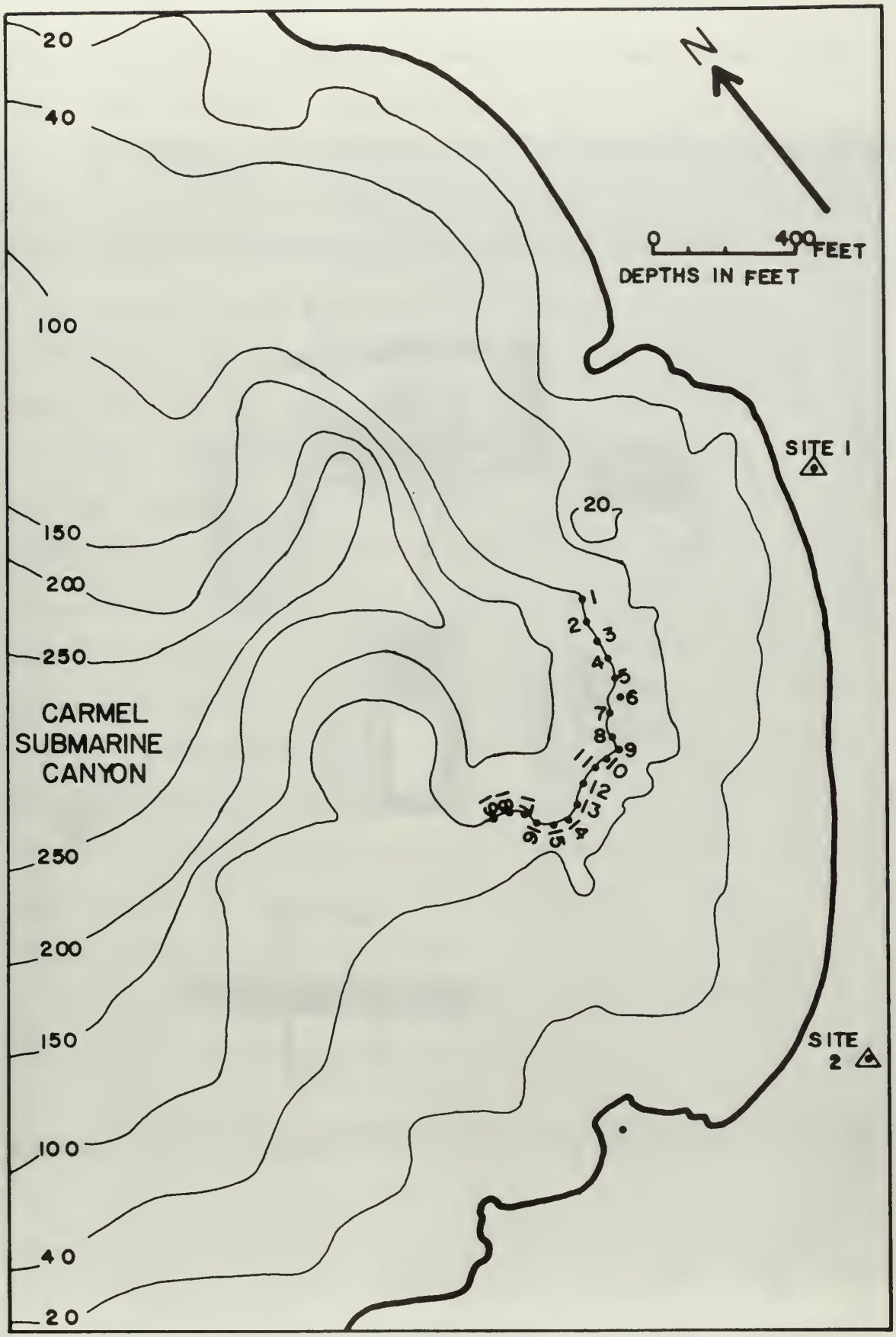

FIGURE 6

Chart Showing Bottom Topography
and Reference-Stake Positions

FIGURE 7

Photograph of Equipment Used

these measurements. Results obtained however, were inconclusive. The location of the stakes is shown in Figure 6.

The reference stakes were made by the Naval Postgraduate School (NPGS) Machine Facility and consisted of 1-inch aluminum I rods, 7 feet in length and marked with a narrow paint strip every 0.1 feet (Figure 7). The stakes were driven into the bottom by means of a tool made of a 3-inch diameter pipe welded shut at one end. The tool was slipped over the top of the stake and by means of handles welded to the sides was used in the manner of a jack-hammer. Stakes were driven along the 100-foot contour at 20-yard intervals. Once the stakes were in place, small aluminum numbering tags were attached to the top with wire clips for identification. Every fifth stake was marked with a small buoy cut from styrofoam, and its position was fixed by means of two transits set up at either end of the beach.

The stake planting operation was accomplished by using four divers and two transit men. The divers positioned a small boat near the point where the first stake was to be planted (adjacent to the rock outcrop on the north wall). The first pair of divers entered the water and found the 100-foot contour using an oil-filled depth gauge. The team of divers remaining in the boat lowered a package of stakes over the side which were retrieved by the submerged team. Stakes had been pre-packaged in groups of five in a manner such that they could be removed individually with the first stake containing a styrofoam buoy. The stake positions were marked by

placing the boat above the underwater position as determined both by the attached buoy and bubbles released by the divers, and calling for a transit fix via walkie-talkie. The distance between stakes was measured by means of a pre-cut line 20 yards in length with metal rings spliced into each end. While one diver held a ring at the just-installed stake, the second diver (with oil-filled depth gauge) would take the other end of the line and swim along the 100-foot contour until the line was taut. Tug signals on the line indicated the arrival at the next position.

The operation proceeded smoothly but was limited by the small amount of underwater time available to complete the work. On the first dive, using single 72 cubic-inch tanks, the bottom time before depleting the air supply for the two pair of divers was 13 minutes and 10 minutes respectively. This was a result of the fact that any work underwater requires much more effort than on land and, consequently, a diver doing work has a higher than normal breathing rate. As a result, both teams of divers planted only a total of seven stakes the first day. At this point it was decided that any future dives requiring work would be done with double tanks to increase bottom time. Regardless of the number of tanks used on a dive, however, the limit of bottom time at 100 feet for a dive not requiring decompression is 25 minutes. In order to be safe, we elected to limit ourselves to dives not requiring decompression. One additional dive completed what we believed at that time to be a sufficient number of

stake installations to satisfy our requirements - a total of 16 stakes covering a linear distance of 320 yards. Three more stakes were later added along the southern wall of the canyon head (Figure 6). The stakes were left in place following completion of this study.

C. BOTTOM SLOPE MEASUREMENTS

Measurements of the slope of the seafloor were taken at each stake position. This was accomplished by means of a navigation board (Figure 7). The board was made locally by the NPGS Machine Facility and consisted of a 12 x 15-inch sheet of 1/8-inch plexiglas engraved with inches along one edge and an arc of angles from 0° to 90° marked every 5°. The bottom slope was measured by means of a plumb line attached to the board, and angles could be estimated to an accuracy of ±2°.

Mounted on the board was an oil-filled depth gauge and an underwater compass. Also engraved on the board was a table for recording camera settings. Notes were taken and measurements recorded by writing on the board with a grease pencil. The navigation board proved to be a most useful piece of equipment. The original board and gauges were later lost in heavy surf and had to be replaced. Slope measurements were taken three times and are presented as Table 1. Slope measurements were affected by kelp pieces and other material lying on the bottom and are therefore only estimates of the sand slope in some areas.

D. SAND SAMPLE COLLECTION

A total of 70 bottom samples for the sediment study undertaken by Wallin (1968) were collected at two separate times. The first group of samples was taken from a small boat by means of a clamshell grab. The boat's position was marked by transit angles from the beach. The clamshell grab proved to be only moderately successful in that the closing mechanism sometimes jammed with the result that no sample was retrieved.

A second set of samples was taken by a more direct means. Two divers were towed by a small boat to areas where the original sampling effort had not been satisfactory. In these areas, a dive to the bottom was made and a sample secured in a small glass jar. Position marking during this sample collection was by sextant angle from the two previously established transit positions on the beach and from two other survey points.

E. PHOTOGRAPHY

During most dives, underwater photographs were taken of both biological and geological features. The camera used was a Rolleiflex model 3.5F in a Rolleimarin underwater housing (Figure 7). The film used throughout was 120 Ektachrome X, ASA 64, using both clear and blue flashbulbs (General Electric 5 and 5B), depending on the subject distance. Initial efforts with the camera were only moderately successful due

to problems with the flash mechanism. When scheduled survey dives began in July, photographs were taken on all dives except those associated with stake installation.

F. BATHYMETRIC SURVEY

The latest published bathymetric charts available for the area around Carmel Canyon are a Coast and Geodetic Survey smooth sheet completed in 1933 (H-5453) and a chart constructed by Shepard and Emery (1941). Both are small-scale charts and do not show the canyon head in sufficient detail for the purposes of this study. Our diving observations indicated both charts to be in error in the area near the rock outcrop on the north wall and also near a rocky area on the south wall of the canyon head. It was therefore considered necessary to conduct a detailed bathymetric survey of the limited area of the canyon head covered by the diving survey. The major responsibility for this work was undertaken by Lieutenant C. L. Kiethly, USN, a graduate student at the Naval Postgraduate School. The survey, in which this writer participated, was conducted using a small boat carrying a battery-operated Apelco Portable Depth Recorder Model MR-201B with the transducer mounted over the side by a specially made clamp device (Figure 7). The boat slowly criss-crossed the area many times in various directions and its position was fixed at 10 to 15 second intervals by two transits located at either end of a base line laid out on Monastery Beach, to which commands were given via walkie-talkie. The fathogram was marked at the moment each position fix was taken. More than 500 fixes were obtained in this manner.

The portable depth recorder is advertised as being capable of recording depths to 240 feet but the maximum depth attained by this instrument was 160 feet. This necessitated another survey of the deeper parts of the canyon head. The deeper survey was performed using the 63-foot NPGS Hydrographic Research Vessel with a Bendix precision depth recorder. Again, transit angle positioning was used.

The area covered by the bathymetric survey is shown in Figure 6. The bottom contours in the figure are at an irregular interval, and were selected so as to display the important topographic features of the seafloor.

DIVING OBSERVATIONS

A. TOPOGRAPHY

The general underwater topography of the area included in our diving survey was quite remarkable in its variation from near-vertical rocky cliffs to almost featureless sand flats. The head of the canyon near Monastery Beach is a sandy bowl-shaped structure with slopes varying from 20° to 30° that is rimmed by the crescent-shaped beach (Figure 8).

The north wall of the canyon head is a steep granodiorite cliff composed mainly of large boulders and rounded country rock (Figure 8). The cliff begins at depths between 20 and 60 feet and continues downward to depths varying between 90 feet and in excess of 200 feet on the canyon wall. At the bottom of the cliff is a sand slope which extends downward at an angle of about 35°. The southern edge of this outcrop extends landward in a direction nearly parallel to the canyon axis (Figure 8). At the southern edge of the sandy bowl at the head of the canyon lies another rock outcrop in the form of a small, narrow ridge at depths ranging from 90 to 100 feet. This ridge is about 12 yards wide and 20 yards long, oriented in a northwesterly direction, and appears to control sand movement locally. It emerges from the sandy slope in an area where the bottom contour contains an adjacent swale which appears to be a slump scar.

At this point, the 100-foot contour turns more toward the west (or seaward) and continues as a sandy slope in a westerly direction for about 120 yards to where two other rock outcrops

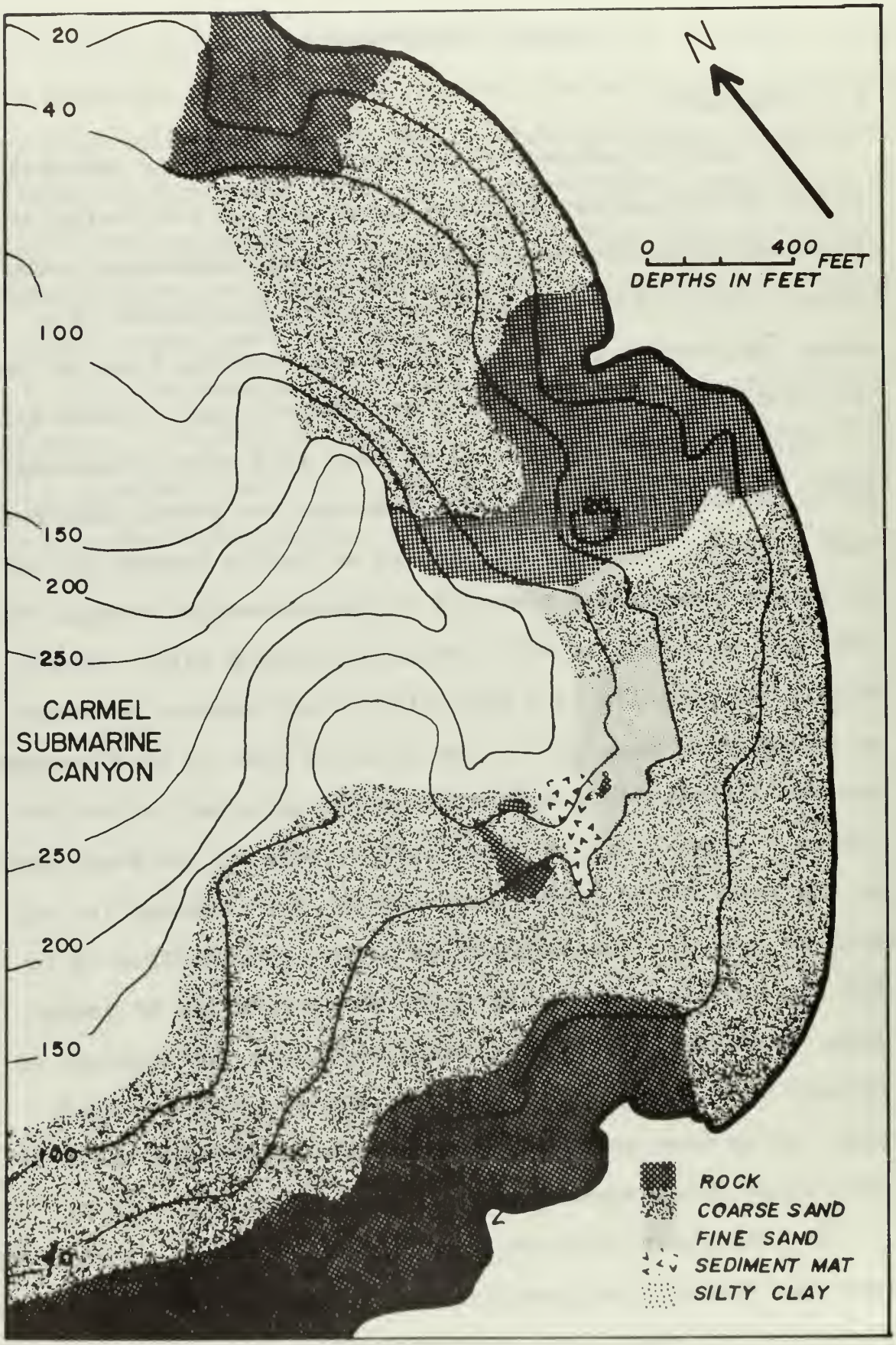

FIGURE 8

Chart Showing Rock Outcrops and Bottom Types

occur adjacent to each other. The shallowest of these exposures extends in a northwesterly direction from 40 feet of water to about 120 feet and appears to control sand movement locally (Figure 8).

About 15 yards in a northeasterly direction from the shallower outcrop occurs a prominent rock mass in the shape of a pinnacle. This outcrop juts out from the steep sand slope at a depth of about 115 feet and rises sharply to a depth of about 90 feet where it levels off for a short distance then drops almost vertically to a depth in excess of 130 feet. This particular outcrop is made up of a single mass of granodiorite. The size of this mass is about 40 yards in an east-west direction and 15 yards in a north-south direction.

Surrounding the canyon head is a broad terrace composed of either rock or coarse sand lying at a general depth of 20 to 30 feet. The canyon axis to the maximum depth of observation is a trough-shaped sand floor.

B. BOTTOM TYPES

1. Rocky Bottoms

Two extensive areas of rocky bottom exist in addition to the rock outcrops previously mentioned. The area between the north rim of the canyon and the shoreline is a granodiorite bottom consisting of boulders from a few feet to several yards in diameter with sand between them. In addition, several granodiorite masses of varying size are exposed in this area. One mass is a rock that is awash (referred to locally as the "wash rock") near the edge of the canyon about 150

yards off shore. This area from the shore to the edge of the canyon is an extension of the granodiorite exposure in the seacliff on the north end of the beach. The entire area is covered by a dense canopy of Macrocystis pyrifera.

On the southern side of the canyon is another area of rock bottom extending outward about 60 to 100 yards along the seacliff (Figure 8). This area is similar in appearance and physical characteristics to the rocky area on the northern side of the canyon head. The entire area is covered by a dense canopy of kelp. This rock-bottom ends abruptly in about 30 feet of water where it disappears beneath a sand bottom.

Rock samples were taken in several places on both the northern and southern sides of the canyon at various depths. The samples were obtained, sometimes with great difficulty, using a geologist's pick. All samples were granodiorite. When first taken, the rock was very hard and some samples appeared to be fresh rock. After a couple of weeks of drying in the air, however, the rock lost its cohesion and pieces several inches in diameter were easily crumbled between the fingers.

All of the rock exposures seen on the seafloor, with two possible exceptions, are composed of granodiorite. During one dive on the rocky terrace at the northern side of the canyon, one boulder of what was thought to be conglomerate was found and a few yards away a boulder of shale (or possibly fine sandstone) was seen. It is not known if these were in fact boulders or rounded country rock. These two rocks

were about 40 yards offshore from the small sandstone and conglomerate outcrop at the northern end of the beach. They possibly originated from or are a part of this formation although large boulders of shale were not found either in the formation or loose on the beach. Subsequent dives to find these rocks for sampling purposes were unsuccessful so that the identification has not been verified.

All exposed rock at depths of less than about 70 feet supports holdfasts of kelp. In shallower depths the rocks are rich in encrusting organisms and various species of kelp which is so thick that swimming is generally difficult. Kelp holdfasts of Macrocystis and Nereocystis torn loose by storms have been found on the bottom and on the beach which contain angular rock fragments and cobbles. On the southern rocky bottom area, Phylospadix (surf grass) was found growing on rocks at depths between the surface and about 15 feet. When a sample of surf grass was pulled from the rock, it was found to be rooted in a 3/4-inch thick mass of encrusting material including sponges, tunicates, and numerous worms of various species. In addition, some of the rock surface in the form of large angular grains was removed along with the encrusting organisms. This suggests that the encrusting organisms play an important role in the submarine weathering of rock.

In some places, the erosion or undercutting of rock was easily observable. This was especially true in areas where the wave surge between the rocks was strong. Much

kelp detritis was observed to be carried back and forth in some of the surge areas. This served to grind up the kelp more finely as well as being a possible aid toward submarine erosion of rocks.

The sand level between the rocks shows evidence of not remaining at a constant depth. Some of the rocks on the southern terrace contain numerous barnacles at a depth of 25 feet. After one period of particularly heavy surf action, the sand level was found to be about 6 inches above the level of the lowest barnacle growth. In addition, a good number of the barnacles had been broken off as much as a foot above the sand level. In this same area, fresh, grey-colored, unencrusted granodiorite was not found without digging at least 6 inches below the sand level. On most dives, however, fresh rock could be found at or an inch or two below the sand level, indicating a relatively stable sand level.

On the rocky parts of the submerged terrace on both sides of the canyon were many well-rounded boulder-like masses extending only a few inches above the sand level. It was not possible to determine whether these were indeed boulders or whether they were weathered or abraided masses of country rock such as is found exposed on the coast. In addition, rock was found in several places within this area by digging a few inches into the sand.

During a deep dive to 200 feet down the rocky cliff along the northern side of the canyon head, the rocks were found to be covered with encrusting organisms. The lack

of allowable time at this depth precluded any sampling of organisms although a photograph taken at 200 feet shows sponges, tunicates, and tube worms (Figure 9). Most of the rocks at this depth were covered by a thin layer of silt. The slightest turbulence created by swimming would cause a small silt cloud to emanate from the surface of the rocks.

2. Sand Bottoms

a. Coarse Sand

The areas of extensive sand bottom only are treated here; sand patches and filling around rocks in the areas of rock bottom are not. Two distinctly different types of sand bottoms were found, areas of coarse sand and of fine sand.

Bottoms consisting of coarse-grained quartz-feldspar sand having few or no benthic organisms form the most extensive areas around the canyon head (Figure 8). Most of the south side of the canyon head between the canyon rim and the rocky bottom area and extending hundreds of yards westward from the large rock outcrop near Stakes #17 to #19 is a shallow-sloped broad terrace of coarse sand. The sand bottom begins in about 30 feet of water and continues toward the canyon to a depth of about 60 feet where an abrupt change in slope occurs from less than 5° to 35°. The sand terrace is characterized by large ripple marks 18 to 20 inches between crests and 4 to 6 inches deep (Figure 10). Their crests are oriented perpendicular to the edge of the steep sand slope but parallel to the dominant wave crests in this area. The steep

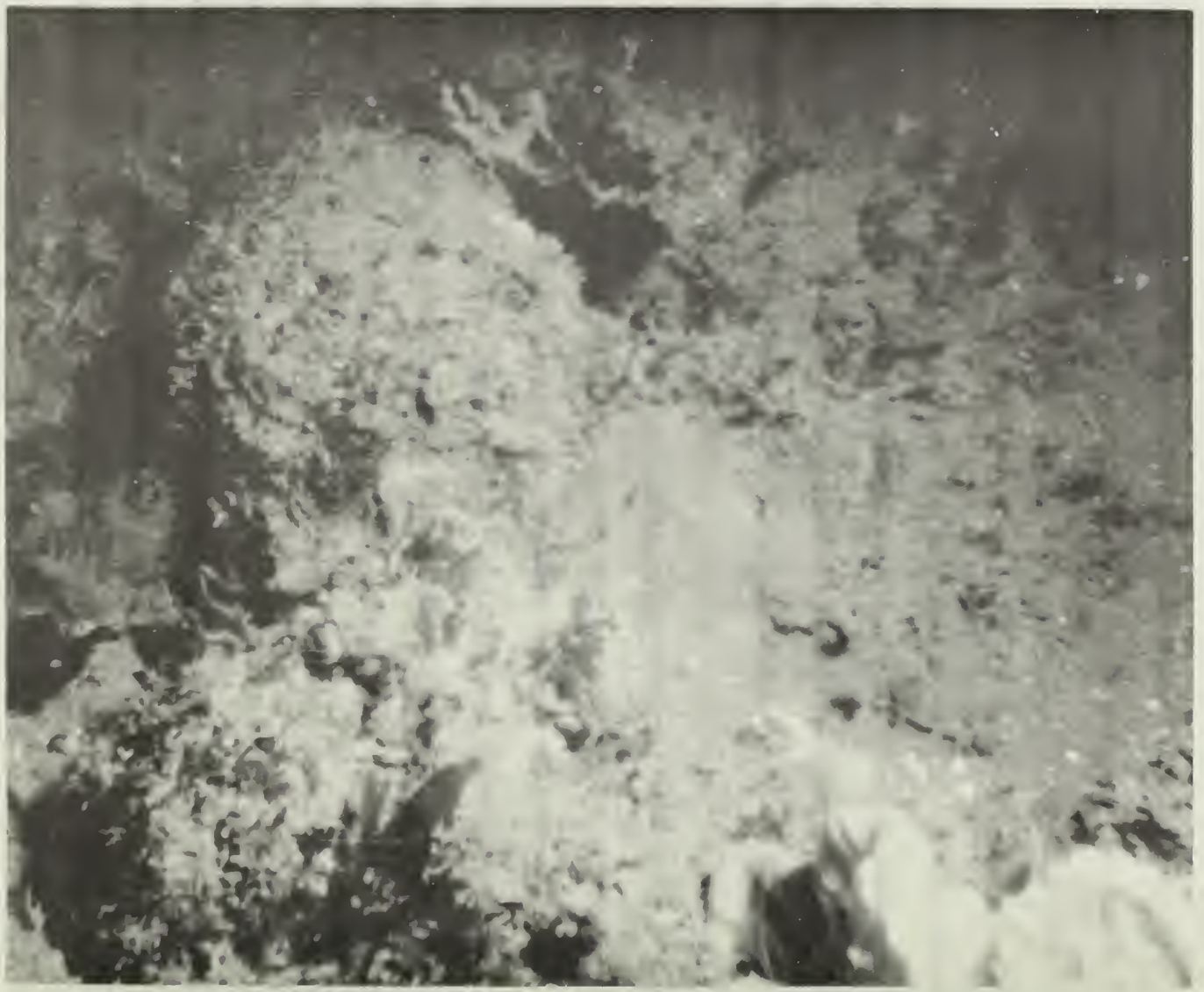

FIGURE 9

Photograph of Rocks at 200 Feet

FIGURE 10

Photograph of Large Ripple Marks

FIGURE 11

Photograph of Coarse Sand Bottom With Beach-Derived Material

sand slope in the canyon has a vertically oriented pattern of fine lines on its surface, similar in appearance to rill marks, which are readily visible. These lines are probably caused by local downslope movement of sand grains by saltation and by abrasion by kelp pieces. This type of bottom appears to be an area of downslope sediment transport although the extent of any mass movement is unknown.

The area between the canyon rim and Monastery beach is also composed of coarse sand. The depth increases rapidly offshore to about 15 feet and then becomes a broad shallow sloped terrace to the edge of the canyon rim in about 60 feet of water. An extension of this coarse sand bottom to the 100-foot level was found between Stakes #3 and #5 following a period of heavy storm swell (Figure 8). The area had a strikingly clean appearance after the storm which it lacked prior to the storm.

The coarse-grained sand normally has small amounts of kelp pieces mixed in with it. Many beer cans, wine bottles, and other beach-derived material was found here (Figure 11). After a period of particularly heavy surf action in October, however, the areas of coarse sand were found to be devoid of beach-derived trash. In addition, some stakes driven into the bottom in these areas were canted downslope. Sand levels and slope angles measured at several stakes were found to be changed (Table 1).

TABLE I

BOTTOM SLOPE AND SAND LEVEL MEASUREMENTS

AT REFERENCE STAKES

(Location of Stakes Shown in Figure 6)

20 August 1968

STAKE NUMBER	SAND LEVEL* (feet)	ANGLE (degrees)	REMARKS
1	1.3	38	canted sideways
2	2.4	34	
3	3.1	32	
4	2.8	25	coarse gravel & pebbles
5	1.0	28	much dead kelp
6	XXX	XX	missed (poor visibility)
7	XXX	XX	missed (poor visibility)
8	XXX	XX	missed (poor visibility)
9	1.6	20	
10	XXX	XX	missed (poor visibility)
11	1.5	24	at foot of outcrop
12	2.0	35	
13	1.8	25	
14	---	--	out of air
15	---	--	out of air
16	---	--	out of air

*The sand level reading is relative to a zero mark at the base of each stake.

TABLE I

(Continued)

10 September 1968

STAKE NUMBER	SAND LEVEL (feet)	ANGLE (degrees)	REMARKS
13	1.8	30	in kelp mat
14	1.8	20	in kelp mat
15	2.7	30	in kelp mat
16	2.4	30	
17	1.7	40	
18	3.0	32	
19	2.2	45	

2 November 1968

STAKE NUMBER	SAND LEVEL (feet)	ANGLE (degrees)	REMARKS
1	Stake down	32	tube worm & fine sand
2	2.6	32	coarse sand & pebbles
3	3.1	32	coarse sand & pebbles
4	2.9	35	coarse sand & pebbles
5	1.2	32	tube worms & dead kelp
6	1.5	20	tube worms & dead kelp
7	1.3	22	dead kelp
8	2.5	15	dead kelp & 3-1/2' bundle
9	1.7	14	fine sand
10	1.8	20	dead kelp
11	1.6	34	rocks

TABLE I

(Continued)

2 November 1968
(Continued)

STAKE NUMBER	SAND LEVEL (feet)	ANGLE (degrees)	REMARKS
12	2.0	32	fine sand
13	1.8	29	slump position - dead kelp
14	1.8	13	dead kelp
15	2.7	37	dead kelp
16	2.3	29	dead kelp
17	1.8	38	medium sand - canted
18	3.0	37	medium sand - canted
19	1.6	35	medium sand

Another extensive area of coarse sand bottom is located to the northwest of the wash rock on the northern canyon wall and terrace. A sandfall into the canyon at the southern edge of this area was observed several years ago by divers (D. F. Ferrin, personal communication).

b. Fine Sand

The fine sand bottoms are distinguished by containing numerous benthic organisms, particularly the burrowing tube worm Diopatra ornata. It is not known how long it takes for these worms to establish themselves, but their existence in such large numbers indicates that these areas are probably very stable with little or no mass sediment movement. The tube worms extend about 6 inches below the surface of the sand. In addition to tube worms there are a number of other sedentary creatures including burrowing anemones, clams, sea pens, etc. The sand in these areas is very fine and easily stirred up by swimming.

A small area of fine sand bottom is located immediately adjacent to the granodiorite exposure on the northern edge of the bowl-shaped canyon head (Figure 8). This area is 30 to 40 yards wide (between Stakes #1 and #3) at 100 feet. The contact between this find sand bottom and the rock outcrop is shown in Figure 12.

A larger area of the same type of sand and with the same benthic organisms is located along the bowl-shaped region of the canyon between Stakes #5 and #10. This area is

FIGURE 12

Photograph of Contact Between Fine Sand and Rock

FIGURE 13

Photograph of Fine Sand Bottom With Beach-Derived Material

located in the uppermost part of the canyon head nearest the beach and is about 100 yards wide. It appears to be inactive as far as mass sediment movement is concerned.

During an early dive into the canyon in the summer of 1967, a large real estate "FOR SALE" sign was observed in the latter area. The sign was still there in August 1968 and apparently unmoved, more than a year later (Figure 13). Occasional beer cans, swim masks, and other recent land-related objects were also found in this area. In addition, observations at 100 feet in this area during periods of heavy swell have shown movement of kelp detritus and saltation of fine sand grains downslope. The presence of tube worms and other organisms, however, is considered to indicate that slumping or rapid mass movement is not common here.

After a period of particularly heavy surf in October 1968, this area was found to be covered in most parts by a layer of kelp fragments from a few inches to a foot or more in thickness. The tubeworms and fine sand, however, were found intact beneath the layer. On another dive, detached kelp moving down the slope was found entangled on Stake #8 and formed a bundle about 3.5 feet high around the stake.

3. Minor Bottom Types

a. Silt Layer

Immediately adjacent to and extending into parts of the rocky bottomed area along the north side of the canyon was found a slightly indirated, unstratified, black micaceous silty clay underlying the sand in about 25 feet of water.

This was first found exposed in the troughs of sandy ripple marks following a period of particularly heavy surf (Figure 14). The silty clay was observed to cover a large area and varied in composition. That found nearest to the beach (about 20 yards offshore) contained much fibrous plant material identified as root fragments of a member of the grass family (E.C. Haderlie, personal communication). A few small calcareous marine worm tubes were found intertwined with the fibrous material. About 50 yards offshore the same type of silty clay was found underlying the sand except that it lacked all traces of plant material. The thickness of the silty clay layer varied between 3/4 of an inch to a foot or more.

Following a heavy storm, a few pieces of this material were found to have been broken loose and became partially buried in the sand. The largest piece found contained fibrous plant material and was about 1 by 2 feet in area and 5 inches thick with well-rounded edges (Figure 15).

The origin of this material is unknown at this time. The high concentration of root material suggests that it is possibly of lagoonal or estuarine origin deposited near the mouth of San Jose Creek during a previous period of lower sea level. It is possible that it was formed under conditions similar to the present salt marsh conditions at Carmel River lagoon (Figure 2). It may also represent an old bed of surf grass that accumulated locally on the sea floor and which entrapped fine sediment particles in suspension that settled into it.

FIGURE 14

Photograph of Micaceous Silty Clay Between Crests of Ripple Marks

FIGURE 15

Photograph of Well-Rounded Chunk
of Silty Clay Material

b. Organic Sediment Mat

One other bottom type occurred in a small area between Stakes #12 and #14. In this area was concentrated thick kelp detritus which is referred to here as an organic sediment mat. The mat lies in a swale adjacent to the rock outcrop previously referred to as a ridge. The swale appeared to be the result of a previous underwater sediment slump. The thickness of the sediment mat could not be readily determined. The mat did not appear to be in an advanced state of decay, and no gas bubbles were seen coming from it. There was no evidence of any movement of the mat. The slope of its surface was about 15°, which is less than the inclination of the sand slopes on either side. The term sediment mat is used here since this phenomenon was similar in appearance and characteristics to the sediment mat described by Dill (1964).

SUMMARY AND CONCLUSIONS

The head of Carmel Submarine Canyon appears to be an extension of San Jose Creek, the land canyon that leads into its head. Granodiorite outcrops on both sides of the canyon head, and is an extension of the rock outcropping on the shore.

The canyon head is in the shape of a round, sandy bowl with a rock wall on the north side and a steep sand slope on most parts of the south wall. Surrounding the canyon rim is a submarine terrace. The terrace is rocky bottomed on both sides of the canyon head and is at the same level, which suggests wave erosion during a previous sea level. The canyon axis is a trough-shaped sand bottom to the maximum depth of observation.

Five distinct types of bottom were found: (1) rock outcrops and boulders, (2) coarse sand, (3) fine sand containing benthic organisms, (4) a silty clay layer underlying coarse sand, and (5) an organic sediment mat.

Downslope movement of sand grains and kelp pieces has been observed on the steep slopes of the canyon head. Submarine erosion is slowly occurring in the rocky areas as a result of mechanical abrasion by the sand. Also effective is the weathering caused by attached or encrusting organisms.

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APPENDIX I

FIELD NOTES OF SCUBA DIVES INTO THE HEAD OF CARMEL SUBMARINE CANYON

Early exploratory dives are not described.

The location of each dive is shown in Figure 5.

DIVE NO. 1

13 July 1968, 0930-1030 PDT, clear, very calm, tide +2.4 ft.

Divers: Team 1, FERRIN, MORITZ

Team 2, GOOGINS, WALLIN

First team planted four stakes on 100-foot depth contour at 20 yard intervals. Air ran out in 13 minutes. Bottom has steep gradient beginning at rock outcrop. Beginning with Stake #1, bottom is composed of fine sand with a large number of tube worms. At about Stake #2, the bottom is covered by dead kelp debris. Visibility about 60 feet.

Second team planted three more stakes for a total of seven. Bottom still has a steep gradient covered by dead kelp.

DIVE NO. 2

16 July 1968, 1000-1100 PDT, clear, moderate surf, tide +2.6 ft.

Divers: Team 1, FERRIN, MORITZ

Team 2, MAUDLIN, WALLIN

First team using double tanks began at Stake #7 and planted seven more. Second team continued with two more stakes until encountering a rock outcrop.

The bottom between Stake #7 and #14 is still covered with dead kelp. Between Stake #14 and #16 is an area of fine sand held by tube worms.

The rock outcrop appears as a northwesterly oriented groin with a few boulders on the western side. Visibility is about 15 feet.

Several dead kelp holdfasts were found in the kelp debris as well as beach derived material such as beer cans and a real estate "FOR SALE" sign. No gas bubbles were seen to be rising from the dead kelp.

DIVE NO. 3

20 July 1968, 0945-1030 PDT, overcast, heavy surf (8 foot breakers), tide +2.9 ft.

Divers: FERRIN, WALLIN, MORITZ

Heavy surf action has thrown much kelp up on the beach, including holdfasts still attached to rocks about the size of volleyballs.

Entered water with double tanks through the surf-line at which time the navigation board carried by Lt. Wallin was ripped away by the surf action. The nylon line used to clip the board to his weight belt had parted. Lt. Wallin was tumbled severely by the surf and was unable to continue the dive.

The loss of the navigation board negated efforts to take sand slope and stake depth measurements.

Dive continued by Ferrin and Moritz. Reached approximate location of Stake #1. Could not find the buoy from that stake and submerged where we thought it should be located. Found #1 immediately. Later discovered that all buoys had broken their lines during the previous week's heavy surf action.

Began attaching numbered aluminum tags to each stake. Between Stakes #3 and #5, the bottom was clean with coarse sand. After Stake #5, the bottom was covered with fine pieces of kelp and trash from the beach. The angle of repose between Stakes #5 and #14, although not measured exactly, was somewhat shallower than that between #1 and #5. At Stake #15 was a rock ridge of as yet undetermined type.

I lost tags #15 and #16, so these stakes were not tagged. After Stake #16, we continued on along the 100-foot contour. Immediately adjacent to the rock ridge is a small area of small boulders with much kelp detritus. This area lasted for about 20 yards. We soon came upon a sand ridge. This area was of coarse sand with a very steep angle estimated about 35° to 40°. Its horizontal dimension is as yet undetermined. Its vertical extent is from about 60 feet on down past 100 feet. This area had an odd appearance in that it had vertical surface marks evident in it. I feel this is an indication of recent or perhaps even continuous sand movement into the canyon. We attempted to set off a sand slide but were unsuccessful. At this point we ran out of air and surfaced.

A few of the stakes were canted over at an angle — not necessarily pointing down canyon. Reason unknown at this time. Could be due to action of the surf tearing away the buoys, other divers being curious, or sand movement.

DIVE NO. 4

3 August 1968, 1030-1145 PDT, fog, light surf, tide +3.5 ft.

Divers: WALLIN, MORITZ

Entered water on South side of beach. Submerged in about 30 feet of water. Visibility about 60 feet. Noticed ripple marks run perpendicular to cliffs along the south side of the bay. The sand is medium to coarse grained. On the seaward side of ripples were dark "shadows" which I believe to be finely ground kelp (about 40 feet). Further out in about 60 feet of water the "shadow" material was of a lighter color grey. I believe the darker material was fresher than the grey material.

The ripples were large, about 16 to 20 inches between crests and about 4 to 6 inches deep.

We found beer cans, snorkels, and other beach derived material in this area indicating bottom movement. However, the "shadow" material indicates that the area has been relatively stagnant recently.

There was a distinct drop off toward the canyon at about 60 feet. The angle changed rapidly. Unfortunately, we couldn't measure it but estimate a change from about 5° to about 25°. We saw a rock outcrop between 80 and 100 feet. The rocks were covered with growth but appeared to be granodiorite. Most of the steeper slope appeared to be relatively stable. Dead kelp was strewn on the bottom, but we were unable to find the very steep area found on the previous dive.

I have the impression that sand moves along the bottom parallel to the cliffs and then dumps at some point into the canyon. The sand found in the ripple area was much the same as that found on the beach.

DIVE NO. 5

6 August 1968, 0900-1000 PDT, clear, light surf, tide +3.9 ft.

Divers: WALLIN, MORITZ

Noticed a detached kelp patch on the southern side of the canyon which was sitting alone and farther out than the rest. We reasoned that this must be the rock outcrop seen on the previous dive and its relation to the rest of the known underwater topography suggested it might act as a barrier to sand transport. There was an open area between the detached kelp patch and the large shoreward kelp bed. Submerged at the shoreward edge of the open space and swam northward toward the lone kelp patch. This open space was about 20 yards in width with a coarse sand bottom containing ripple marks 18 to 20 inches between crests and 4 to 6 inches deep. The bottom in this area (about 40 feet) was being slightly disturbed by the swell as some of the finer sand grains were being moved. The ripple marks were also "shadowed" on the seaward side with finely ground dark colored kelp which indicated an early state of deterioration.

We found an outcrop of granodiorite boulders and masses at about 60 feet rising to 40 feet in some spots and then dropping downslope to past 100 feet. The rock surfaces were

DIVE NO. 4

3 August 1968, 1030-1145 PDT, fog, light surf, tide +3.5 ft.

Divers: WALLIN, MORITZ

Entered water on South side of beach. Submerged in about 30 feet of water. Visibility about 60 feet. Noticed ripple marks run perpendicular to cliffs along the south side of the bay. The sand is medium to coarse grained. On the seaward side of ripples were dark "shadows" which I believe to be finely ground kelp (about 40 feet). Further out in about 60 feet of water the "shadow" material was of a lighter color grey. I believe the darker material was fresher than the grey material.

The ripples were large, about 16 to 20 inches between crests and about 4 to 6 inches deep.

We found beer cans, snorkels, and other beach derived material in this area indicating bottom movement. However, the "shadow" material indicates that the area has been relatively stagnant recently.

There was a distinct drop off toward the canyon at about 60 feet. The angle changed rapidly. Unfortunately, we couldn't measure it but estimate a change from about 5° to about 25°. We saw a rock outcrop between 80 and 100 feet. The rocks were covered with growth but appeared to be granodiorite. Most of the steeper slope appeared to be relatively stable. Dead kelp was strewn on the bottom, but we were unable to find the very steep area found on the previous dive.

I have the impression that sand moves along the bottom parallel to the cliffs and then dumps at some point into the canyon. The sand found in the ripple area was much the same as that found on the beach.

DIVE NO. 5

6 August 1968, 0900-1000 PDT, clear, light surf, tide +3.9 ft.

Divers: WALLIN, MORITZ

Noticed a detached kelp patch on the southern side of the canyon which was sitting alone and farther out than the rest. We reasoned that this must be the rock outcrop seen on the previous dive and its relation to the rest of the known underwater topography suggested it might act as a barrier to sand transport. There was an open area between the detached kelp patch and the large shoreward kelp bed. Submerged at the shoreward edge of the open space and swam northward toward the lone kelp patch. This open space was about 20 yards in width with a coarse sand bottom containing ripple marks 18 to 20 inches between crests and 4 to 6 inches deep. The bottom in this area (about 40 feet) was being slightly disturbed by the swell as some of the finer sand grains were being moved. The ripple marks were also "shadowed" on the seaward side with finely ground dark colored kelp which indicated an early state of deterioration.

We found an outcrop of granodiorite boulders and masses at about 60 feet rising to 40 feet in some spots and then dropping downslope to past 100 feet. The rock surfaces were

covered by sponges, tunicates, bryozoa, and anemones. A sample of rock was taken with a geologist's pick. The sample was indeed granodiorite similar to that on the cliff with a high biotite content and containing phenocrysts of quartz.

Some dead kelp was found imbedded in the sand next to and between the rocks. This kelp was in an advanced state of decay which had discolored the sand to grey for several inches around it. This indicated that there was little or no sand movement between or among the rocks.

The flash mechanism of the camera failed to operate on this dive so we were unable to record several of the interesting observations.

We swam around the outcrop on the seaward side and then back toward the beach at about 80 feet. Immediately adjacent to the rock outcrop on the shoreward side was a sharp dropoff running in an almost east-west direction. (Also the bottom appeared to deepen rapidly on the Northern and Western sides of the outcrop.) This sharp dropoff began in about 60 feet and continued downward past 100 feet. The angle of repose varied between 30 and 40 degrees. There was no sign of any bottom growth in this area. We did find a beer can and a few pieces of kelp fronds several inches long. These kelp fronds could actually be seen moving downslope at 80 feet. We could also see some of the finer sand grains being moved by the action of the swells. The swell would pitch up a few grains and deposit them about 4 inches further down the slope.

At 60 feet where the slope begins there are large ripple marks perpendicular to the edge of the slope. These ripple marks stop just over the edge of the crest of the slope. This area of apparent activity is estimated to be about 40 yards wide and bordered to the east by an area of slightly smaller slope and different type bottom. This area was covered with much dead kelp in varying states of decay. We also came upon a small rock outcrop extending from 80 to 100 feet. We found Stakes #13, 14, 15, and 16 in this area but discovered that we had stopped our stake planting operation prior to encountering the active area. In this small outcrop was a crevass filled with dead kelp of undetermined thickness.

DIVE NO. 6

10 August 1968, 0915-1000 PDT, overcast, very light surf, tide +4.8 ft.

Divers: WALLIN, MORITZ

Submerged on top of rock outcrop explored during last dive. Visibility 15 to 20 feet due to plankton bloom. Began working to seaward (westward) from rock outcrop in about 40 feet of water. Slope gradually increased as we advanced seaward. The bottom was composed of fresh sand of medium to coarse size. Not much kelp mixed in with sand. Occasionally small pieces of kelp were found partially covered with sand.

Eventually a sharp ledge was found in about 60 feet of water. The angle beyond this ledge varied as we went seaward from 25° to about 45°. Again, pieces of kelp were observed

moving down the slope of the canyon. A few starfish were found on the slope — some visually moving up the slope.

Occasionally a small mound of fresh sand could be found indicating the presence of a burrowing organism. No bottom attached vegetation or organism was found in this area.

The ledge and slope continued seaward with some anomalies in direction. We swam for several hundred yards along the slope with no marked variation in appearance. The sand all appeared to be of the same type and size. Notably absent were land derived items such as beer cans, etc.

The anomalies in direction were compared with charts after the dive and appear to be as indicated on the chart. Also notably absent today was any sand movement caused by swell or waves but then the swell was unusually small today.

DIVE NO. 7

13 August 1968, 0910-1000 PDT, overcast, light surf, tide +3.2 ft.

Divers: WALLIN, MORITZ

Submerged almost directly to Stake #1 in 100 feet of water. No visible sign of activity regarding sand movement at #1. Swam seaward (west and northwest) along the rock outcrop at depths between 60 and 100 feet. This rock outcrop consists of large boulders and masses of granodiorite with the smallest boulders about 4 feet across and of unknown depth below the surface. Did not notice any preferred direction of faulting.

All the rocks were covered with growths of sponge, bryozoa, algae, anemones, and other types of plants and animals.

A large rock awash is associated with this outcrop and the rock type can be seen to continue onto the beach. Sand was found in the crevasses between the rocks.

There was a plateau at about 60 feet with much sand and not too much rock protruding. There was bottom growth here and rotting pieces of kelp indicating little or no activity. This area is probably a hanging valley.

The rock at times dropped off from depths of 60 to greater than 120 feet.

We followed the outcrop westward and northward until we came to another sand area at the Northwestern extremity of the rock outcrop. This area was a relatively flat terrace area at about 60-foot depth and then dropping down into the canyon with an angle of about 35°. This sand was coarse and did not have heavy bottom growth nor did it have large ripple marks. At this point we ran out of air and surfaced.

FIELD TRIP

17 August 1968

Surf was too rough to enter water with any degree of safety. Breakers were 6 to 8 feet high with a period of about 12 seconds. It appeared as though the beach profile was steepening and receding.

We walked along the south edge of the bay and climbed the rocky cliffs. The rocks were granodiorite with a thin 1 to 2 foot veneer of soil and gravel along most of the upper edge of the cliffs. The rock was weathered with no fresh rock evident anywhere.

We then went around the northern end of the beach and found the rock outcrop to also be granodiorite. Conglomerate on the north end was also found in one place. Some of the rock along the northern end was selectively weathered. Again no fresh rock was found. The granodiorite was also exposed along the top of a knoll. Boulders along the beach below this knoll were about the same size as that found along the slopes of the underwater outcrops. It appears that the rock structures on either side of the canyon are continuations of one another.

DIVE NO. 8

20 August 1968, 0905-0945 PDT, clear, moderate surf, tide +3.7 ft.

Divers: WALLIN, MORITZ

Submerged at Stake #1. Visibility was less than 10 feet above a depth of 60 feet and about 10 to 15 feet below a depth of 60 feet. Found Stake #1 with no problem and began taking stake readings.

Between Stakes #3 and #5 there was no bottom growth at all and the sand was of a very coarse consistency with some small gravel. This is a definite change from before. There were lines or patterns in the sand which indicated that it had been moving directly down the slope. From #5 on we found tube worms and other growth on a very fine sand bottom. The only change in this area was that less dead kelp was found lying on the bottom than previously observed. This consisted mostly of frond parts and some of these pieces could be seen being moved

down the slope by the action of the swell. The swell also caused a slight movement in some fine sand particles. The abundance of tube worms however, kept any significant sand movement from occurring. Some areas were more heavily covered with kelp.

I believe last week's heavy weather caused some sand movement off the beach and down the slope between Stakes #3 and #5. There were no other areas of active sand transport found on this dive. We ran out of air at Stake #12 and surfaced (measurements presented in Table I).

DIVE NO. 9

24 August 1968, 0930-1015 PDT, overcast, moderate surf, tide +4.7 ft.

Divers: WALLIN, LENNOX

(Due to illness I could not make this dive. These notes are from Lt. Wallin.)

Launched the boat from Whaler's Cove and proceeded to the detached kelp patch. Both divers donned a set of doubles and descended. Bottom was contacted at 60 feet.

Swam along canyon rim trying to locate the kelp stipe previously placed in the sand. It has apparently been swept away. Descended the slope and found Stake #14. Continued to swim south and tagged Stakes #15 and #16.

Surfaced to get stake driving equipment. Descended with stakes and driving equipment and missed the slope. Overshot to a depth of 125 feet and had to swim hard to avoid being swept into the canyon.

Approximately 20 feet from the location of Stake #16 is the beginning of a rock (granodiorite) ridge. This ridge is in such a position as to disturb the slope and any down-canyon flow of sediment along this section of slope. This area requires much more investigation.

Placed Stakes #17, #18 and #19 along sand slope on inboard side of ridge. Stake #19 is at the foot of an outcrop presumed to be the outcrop which hosts the kelp patch.

The bottom of the area of #17, #18, and #19 is sand with appreciable growth or sediment mat. It can possibly be inferred that the sediment is in motion.

DIVE NO. 10

7 September 1968, 0915-1000 PDT, clear, light surf, tide +5.2 ft.

Divers: WALLIN, MORITZ

Diving for sand samples in various parts of the canyon head. We were towed by a boat from area to area, then dived to obtain samples in a small jar. Location was marked by transit angles from the boat operator. Sixteen samples were taken in this manner.

Then went to look at the south rock outcrop. It begins in about 40 feet of water and continues to about 110 feet of water. It consists of boulders and masses with sand between. At 110 feet it appears to drop off sharply as sand at an angle of about 25 degrees. A few yards to the northeast at 110 feet begins another outcrop which rises sharply to a depth of about 90 feet. This is a large outcrop consisting of a single rock

mass (i.e., not boulders), about 40 yards in length, and 15 yards in width. On the canyon side of this rock is a steep cliff extending nearly vertically past 130 feet to an unknown depth. At this point we ran out of air and surfaced.

DIVE NO. 11

10 September 1968, 0845-0930 PDT, clear, light surf, tide +4.2 ft.

Divers: WALLIN, MORITZ

Submerged at southern rock outcrop in 60 feet of water. Swam to Stake #19, tagged it with a numbered aluminum tag and took measurements. This stake is immediately adjacent to the rock outcrop. From this stake I could see the deeper outcrop about 15 yards to the northeast. Visibility about 60 feet. Swan to Stake #18, and took measurements. The gully formed between the deeper outcrop and the steep sand slope contained gravel, shells, beer cans, a dive mask, and very coarse sand. There was also a large amount of dead kelp. Continued taking measurements up to Stake #13. The bottom appears to have changed slightly in this area. Much kelp had moved down the slope as was evidenced by kelp stipes being draped around and hung up on the stakes. Between #17 and #14 there was much kelp on the bottom. I could not determine the thickness.

The visibility was so good that I could determine that the bottom did not have a uniform slope between #14 and #17. There are also some rock boulders in the area which were not seen today (Measurements listed in Table I).

DIVE NO. 12

14 September 1968, 0850-0940 PDT, overcast, moderate surf, tide +3.6 ft.

Divers: WALLIN, MORITZ

Entered the water in the kelp bed on the northern side of the beach and swam toward the wash rock. The bottom is rocky with sand between boulders in most places. A heavy growth of many types if kelp and other encrusting organic material covers these rocks. We found no fresh rock in the central area. The lead in the kelp where we swam out seemed to be an intrusion of sand between two rows of boulders. These boulders ranged in size from cobble to 10 by 10 yards with no apparent dominant size. Several places had cobble bottoms or exposed rock bed, generally at a depth of 25 feet.

The edge of the rocky bottom is distinct. Most of the area near the edge appears to be a rock table at a depth of 25 feet. We found fresh rock on vertical faces in this area in contact with the sand level. There is also some exposed fresh rock of sedimentary origin. One barely exposed rock appeared to be shale or fine sandstone while another was conglomerate. Both were well rounded.

DIVE NO 13

12 October 1968, 0910-1000 PDT, overcast, moderate surf, tide +4.1 ft.

Divers: WALLIN, MORITZ

Due to the high surf which precluded diving on 8 October, the beach face was noticeably chewed back. The foreshore seemed to be flattened with a very steep backshore.

We entered the water on the south end of the beach and submerged at the near edge of the kelp bed in 22 feet of water. Rock masses and boulders were found immediately.

There was much detritus on the bottom being moved by the surface swell. The sand level on the rocks was about 6 to 8 inches higher than would be expected in that marine growth extended 6 to 8 inches below the present sand level at which point fresh rock was found. Barnacles on some rocks had been broken off near the sand level as though the sand might have scoured them off.

There was a heavy surge between outcrops which visibly moved large amounts of detritus. In most heavy surge areas, the bottom consisted of well-rounded granodiorite cobbles.

As on the northern side, there seems to be a rock table at a depth of 22 to 30 feet with a thin veneer of sand in some areas between outcrops. Vegetation on the rocks and general geological characteristics appeared to be the same as the northern rocky bottomed area except that surf grass was found growing on one rock in this southern area. I pulled loose some surf grass and found that the roots were anchored in about 3/4 inches of sponge and other growth. Some rock grains came with the undergrowth. Numerous worms were found within the roots.

DIVE NO 14

26 October 1968, 0915-1040 PDT, overcast, moderate surf, tide +4.9 ft.

Divers: FERRIN, MORITZ

Attempted today to dive on an area where Cdr. Ferrin has witnessed a sand fall. This area is about 60 yards northwest of the wash rock on the northern side. In addition we planned on following the slope down to a depth of 200 feet.

Submerged at suspected sand fall point. Reached bottom at about 70 feet on a precipitous rocky cliff. These rocks were of large boulder size or could have been part of the outcrop mass. The angle was very steep at about 50 to 60 degrees. This continued downward for an undetermined distance. We stopped the descent at 200 feet. The light attenuation was great at this depth and we were unable to see without the aid of a light. The rocks at this depth were covered by a fine silt very much like dust. The slightest turbulence created by swimming would stir up the silt like a dust cloud. The encrusting organisms could not be identified, but the rocks were definitely covered with growth.

The time allowed for a 200-foot dive is limited to 5 minutes counted from the surface. For this reason the dive was a "bounce dive" or a rapid descent to 200 feet and then an immediate ascent.

A sand contact with the rocky cliff was not found. Cdr. Ferrin believes we were about 50 yards south of where the sand fall had been seen.

On the swim back to the beach, I submerged again at the edge of the kelp bed about 50 yards from shore in about 25 feet of water to look for the shale and conglomerate boulders found on a previous dive. These boulders were not found. In this location, however, at the edge of the rocky bottom area, a black sedimentary substance was found in the bottom between the crests of ripple marks. It appeared as though the ripple marks were formed over a bed of this black substance. The substance was about the consistency of molding clay. I dug up a piece of it and found that as I moved it through the water, it disintegrated due to the turbulence of the water. I feel certain that it consisted almost entirely of black mica flakes although I was unable to bring back a piece for analysis.

About 15 yards in closer to the beach, another area was found which appeared to have the same type of substratum. This again was in 25 feet of water at the edge of the rocky-bottomed area. Another sample was dug up and disintegration occurred as before. There was a difference, however, in composition. The deposit nearest shore contained a considerable amount of fine vegetable material homogeneously distributed within the mica.

DIVE NO. 15

31 October 1968, 0845-0945 PST, overcast, moderate surf, tide +4.4 ft.

Divers: WALLIN, MORITZ

Submerged at edge of kelp bed on north side about 20 yards off-shore in 25 feet of water. Looking for clay-like material found on last dive and shale and conglomerate boulders found on earlier dives. At 25 feet found a piece of clay-like material about 6 by 6 inches which appeared to have been broken loose and was well rounded on the edges. This particular piece had much vegetable matter intertwined. Don't know at this point if the vegetable matter is of land or marine origin.

A little further out found more of the same material covered with a thin layer of sand. This material did not have as much vegetable matter in it. Unable to determine the size or extent of the clay-like material.

All along the edge of the kelp, I could dig a few inches down into the sand and find either very fine dirty sand or clay-like material. The covering sand, however, was quite coarse and clean.

About 50 yards from shore, the clay-like material was entirely without vegetable matter. Some broken off pieces were found to be about 1 to 2 inches thick and well rounded. This material washes away quickly in any turbulence if broken. The same is true for the material with vegetable matter. Samples of both types were obtained in jars.

The conglomerate or shale boulders were not found.

DIVE NO. 16

2 November 1968, 0925-0948 PST, overcast, light surf, tide +4.9 ft.

Divers: BOND, WALLIN

(Due to illness I could not make this dive. These notes are from Lt. Wallin.)

Launched the Boston Whaler at Whaler's Cove and proceeded to a point 20 yards south of the wash rock. Entered the water with double 72's and contacted the bottom at 65 foot depth. Swam downslope to location of Stake #1. Stake #1 was found at the correct location but lying on the bottom. No portion of the stake was penetrating the bottom and the buoy line which was on this stake at last sighting was gone. The stake was probably pulled up by another diver. The bottom in this area and to a point halfway between Stakes #4 and #5 is very coarse sand with considerable pebble content. There is a very sharp transition at this point from coarse sand to fines held by worm tubes. By the time we got to Stake #5 the bottom was covered by broken kelp and fine sand. This bottom condition continued until shortly before Stake #16. Stake #16 was placed in fine sand held by worm tubes. Halfway between Stake #16 and #17 there was another sharp transition to medium sand which continued to the end of the stake array at #19. The detritus collection area just downslope from Stake #17, as previously noted, was completely clean with nothing but medium sand in the entire area. Noted readings from Stake #19 at 20 minutes elapsed time since submergence. Ascended

canyon slope between the rock outcrops to the canyon rim at 70 foot depth. Surfaced after 23 minutes. All stakes were found and recorded. Upslope from Stake #13 there appears to be an old slump or slide scar which extends upward to the rim. The "FOR SALE" sign seen in previous dives was not seen on this dive — possibly covered by kelp.

APPENDIX II

LIST OF MAJOR REFERENCES REVIEWED CONCERNING SUBMARINE CANYONS AND UNDERWATER OBSERVATIONS

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13. ABSTRACT

Scuba dive observations made in Carmel Submarine Canyon revealed the existence of rock outcrops of granodiorite on both sides of the canyon head. Five distinct bottom types were found: (1) rock outcrops and boulders, (2) coarse sand, (3) fine sand containing benthic organisms, (4) a silty clay layer underlying coarse sand, and (5) an organic sediment mat. Rocky bottomed terraces on both sides of the canyon head are at the same level and appear to have been eroded at a previous lowered sea level. The coarse sand areas, characterized by steep slopes, are considered to be areas of active sand movement. The fine sand bottoms were found to be relatively stationary although dead kelp material moves over its surface. Thin silty clay deposits considered to be of lagoonal or estuarine origin are found underlying sand at the north side of the canyon head. An organic sediment mat of undetermined thickness was found in a swale which appeared to be a slump scar. Mechanical erosion of the rock from both sand movement and the action of encrusting organisms is evident.

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	ROLE	WT	ROLE	WT	ROLE	WT
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